

# Benchmarking: What's Your Building's Energy IQ?

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Presentation at *Sustaining the Future*

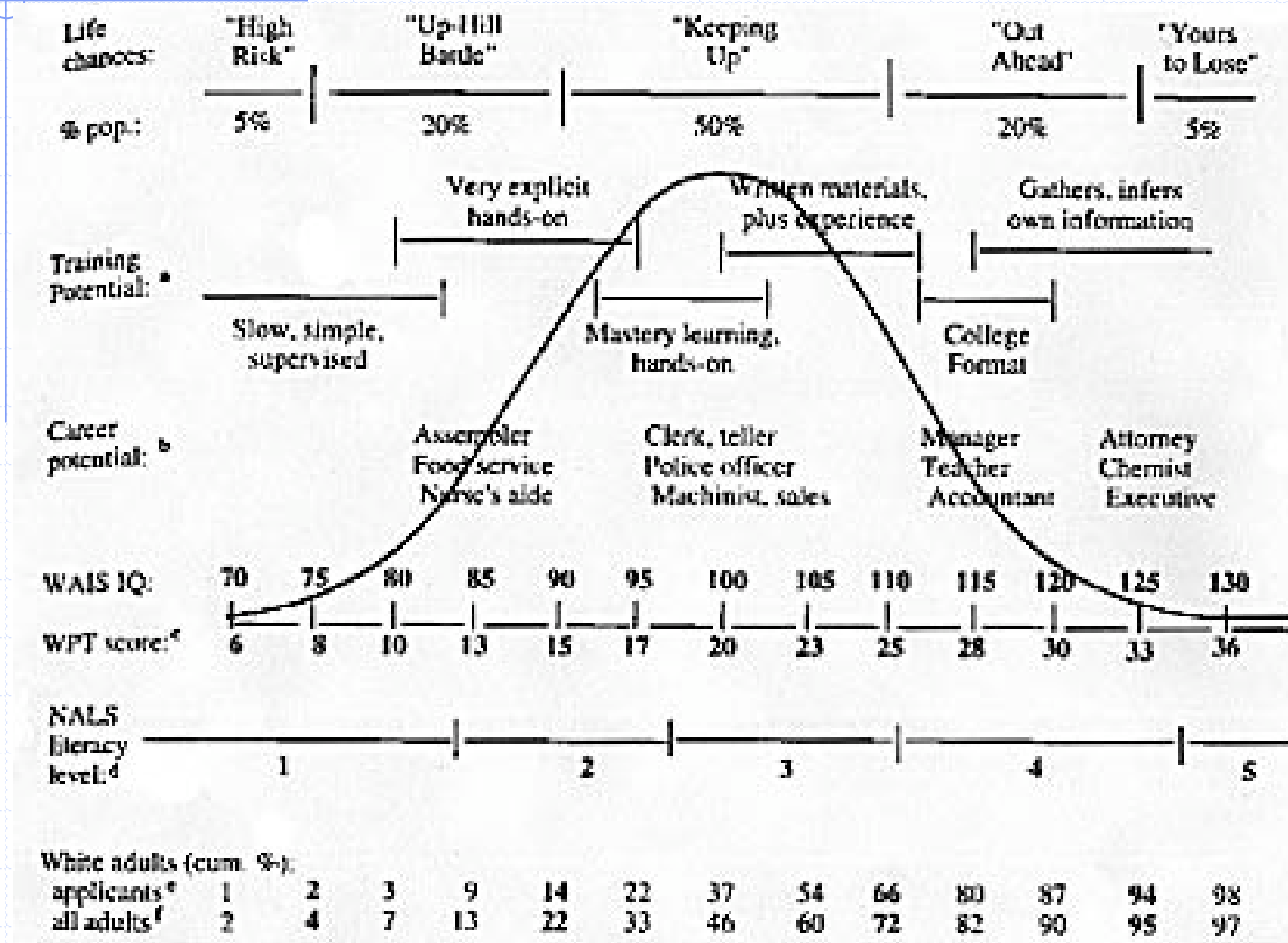
Hawaiian Electric Co., Sept. 26, 2003

# Talk Outline

- ◆ What's Energy Benchmarking Anyway?
- ◆ Techniques
- ◆ Complications
- ◆ Applications
- ◆ Tools

√ For list, see: <http://poet.lbl.gov/cal-arch/links/>

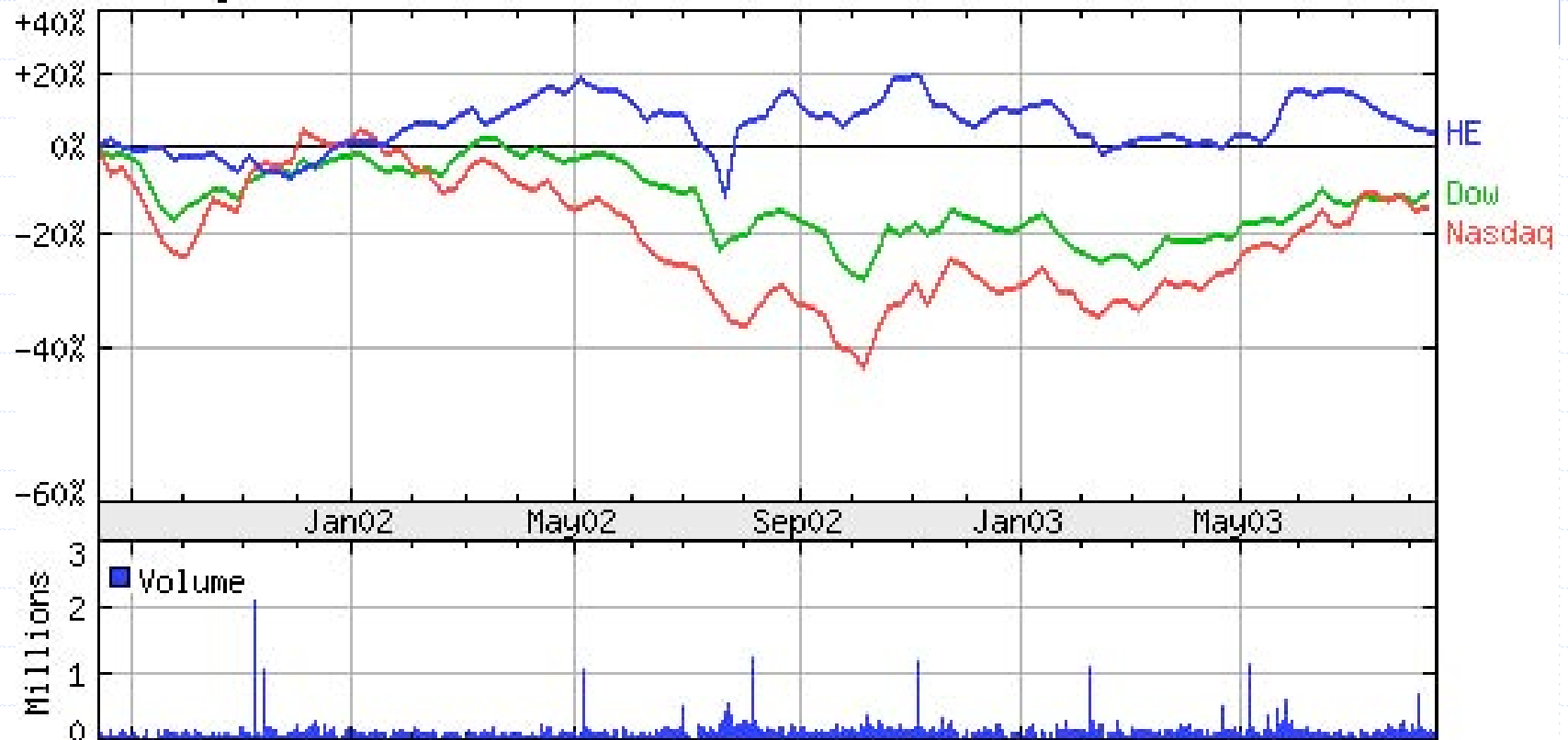
# Familiar Benchmarks: IQ



# Benchmarks are Everywhere

HAWAIIAN ELEC  
as of 14-Aug-2003

Splits: ▼

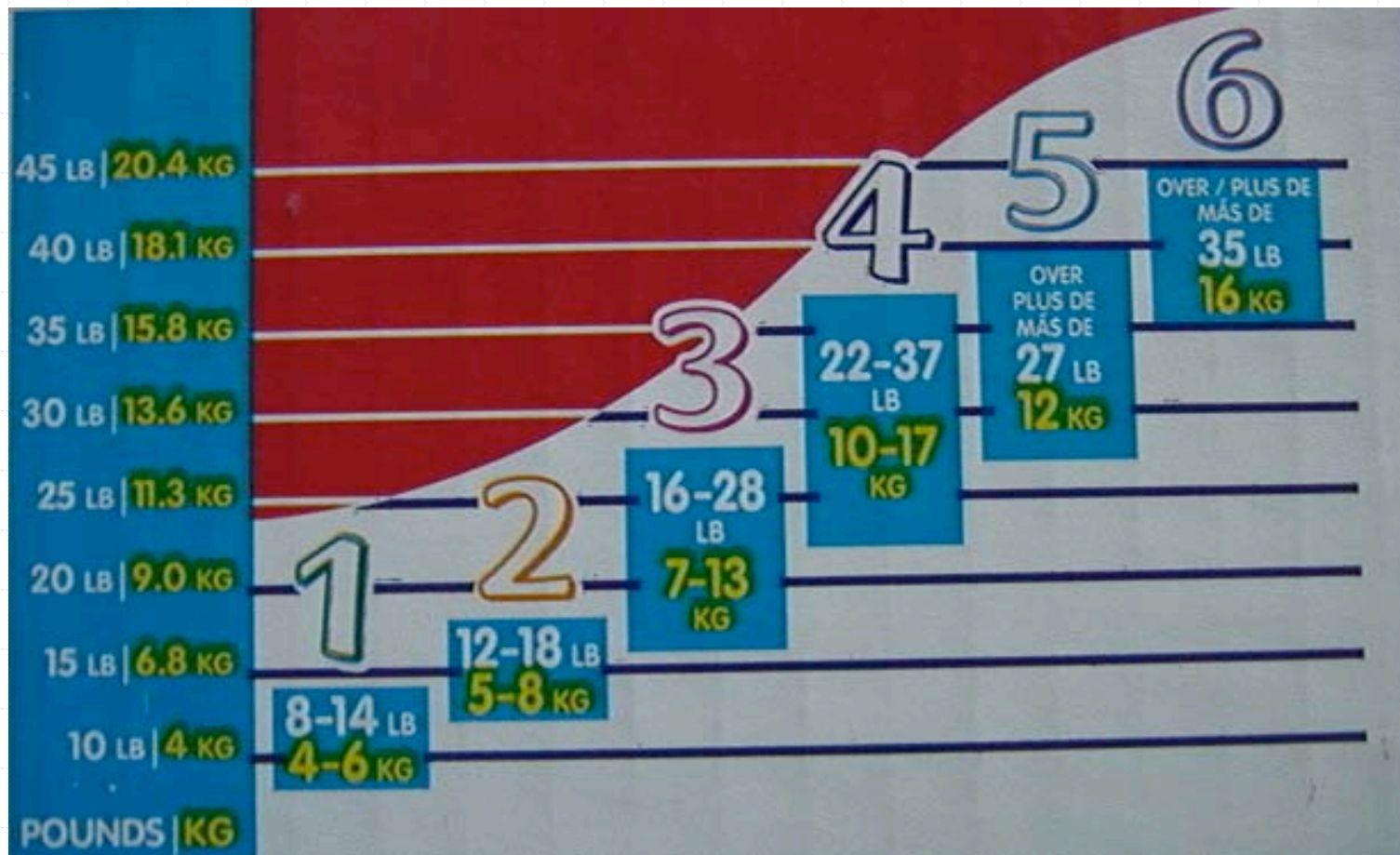


Copyright 2002 Yahoo! Inc.

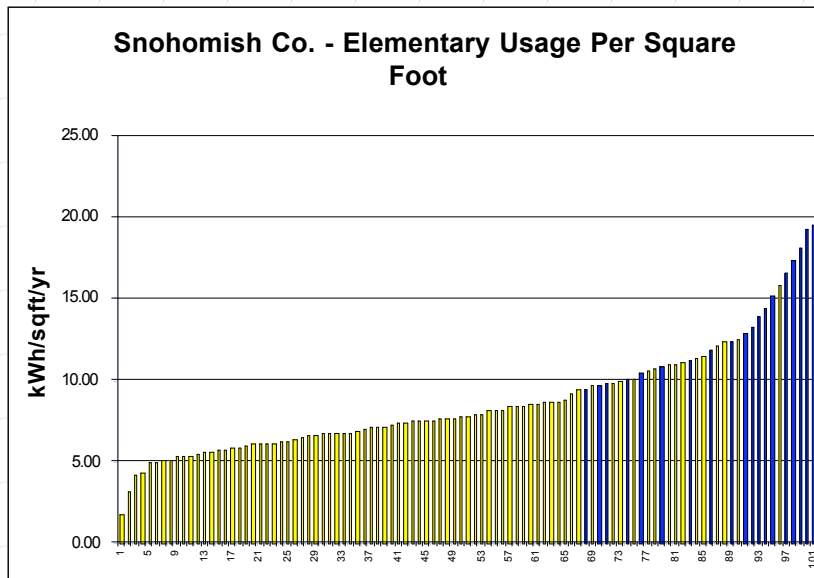
<http://finance.yahoo.com/>

# Huggies: Diaper Size as “logit” Function of Child Weight

Nice chart; dubious value in real world



# Why Benchmark?



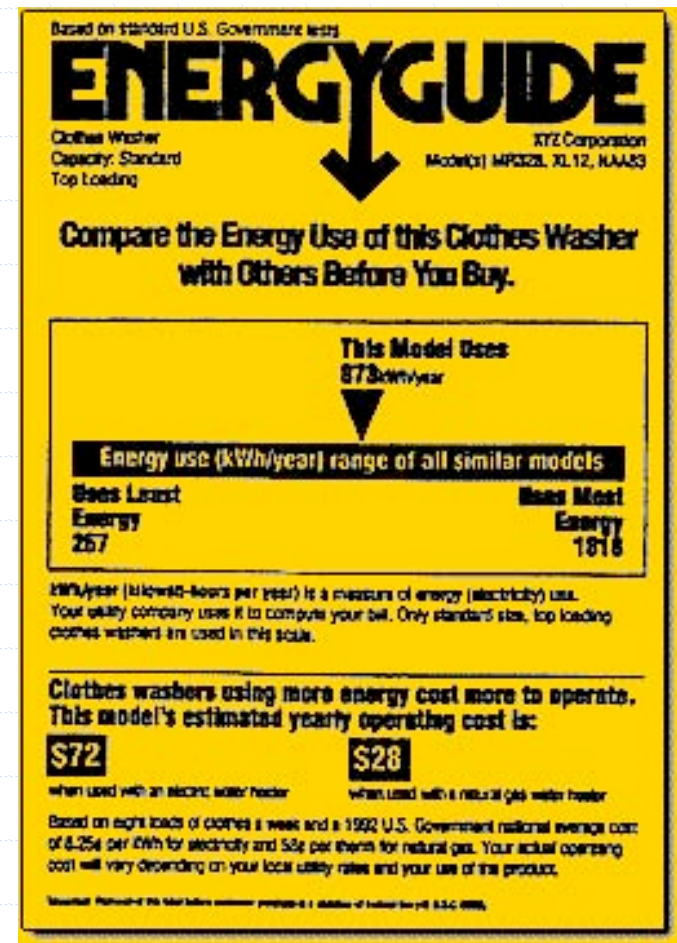
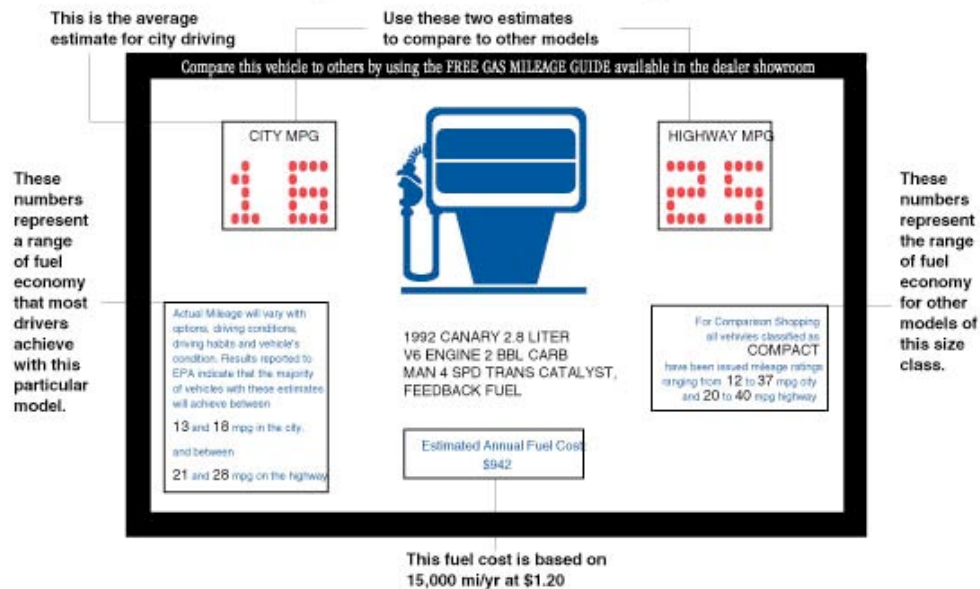
- ◆ Establish baseline and track performance
- ◆ Validate design
- ◆ Identify maintenance and control problems
- ◆ Identify best practices; set goals or standards
- ◆ Identify savings potential
- ◆ Prioritize efforts
- ◆ Educate; Inspire!

# Familiar Energy Benchmarks ...

...Fundamental differences in approach

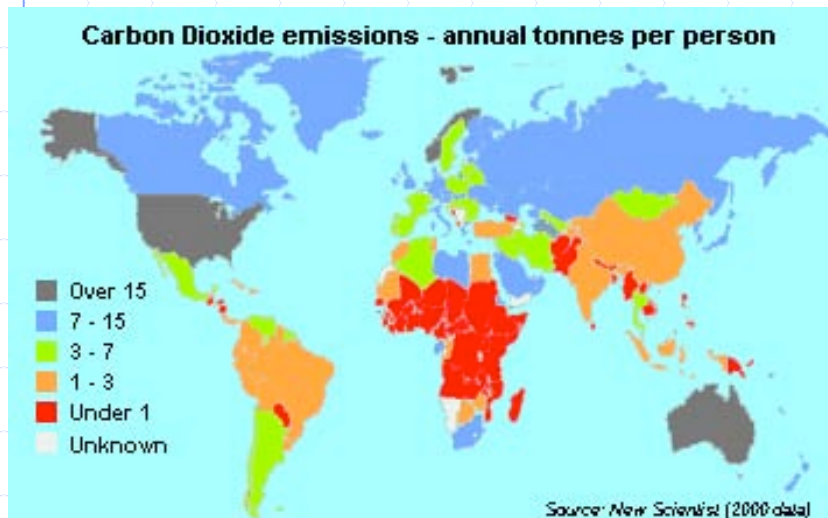


Sample Fuel Economy Label  
(Attached to New Vehicle Window)

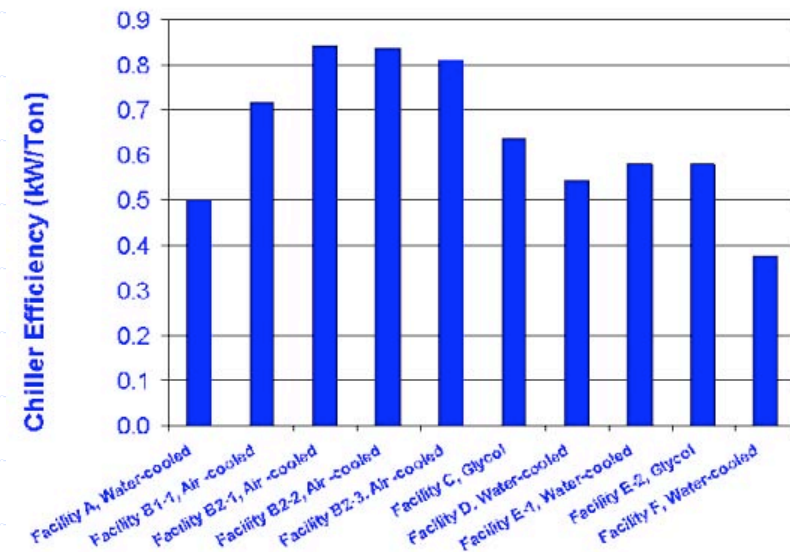


# Benchmarking Can Be Done at Any Scale

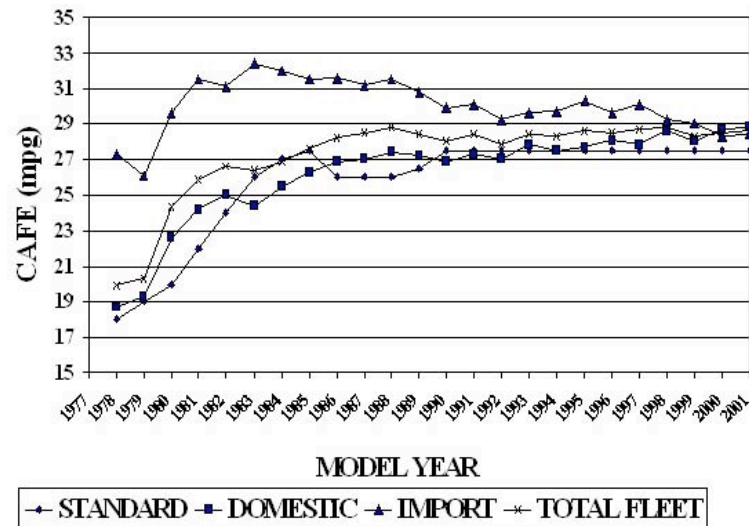
- Global CO<sub>2</sub>/Capita



- Chiller efficiency

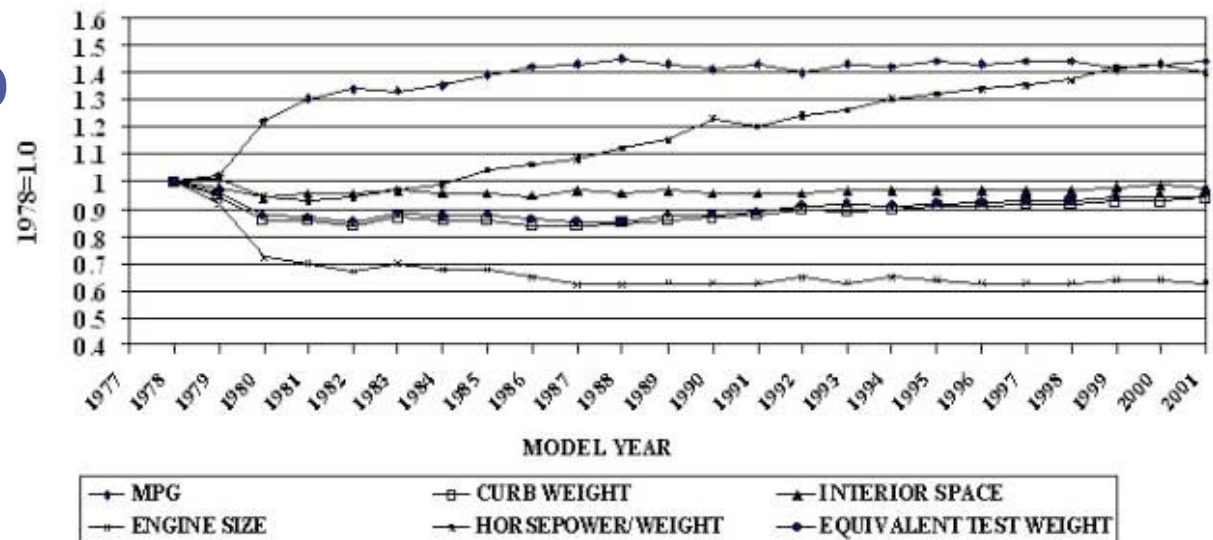


# Choice of Benchmark Determines Conclusions



◆ Important to isolate sub-groups of interest

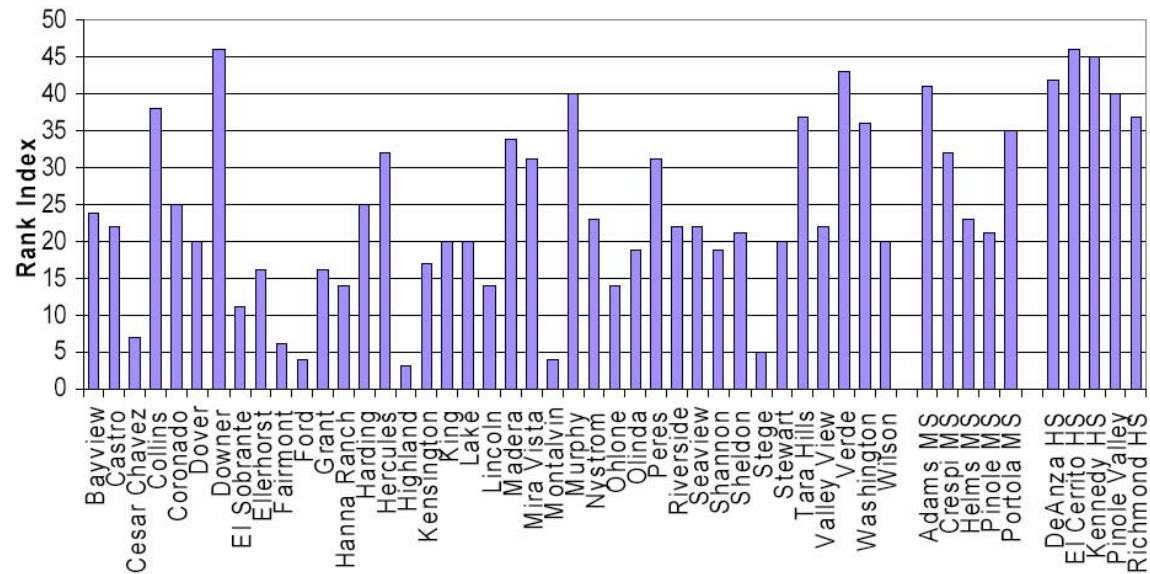
◆ Many ways to benchmark a given system



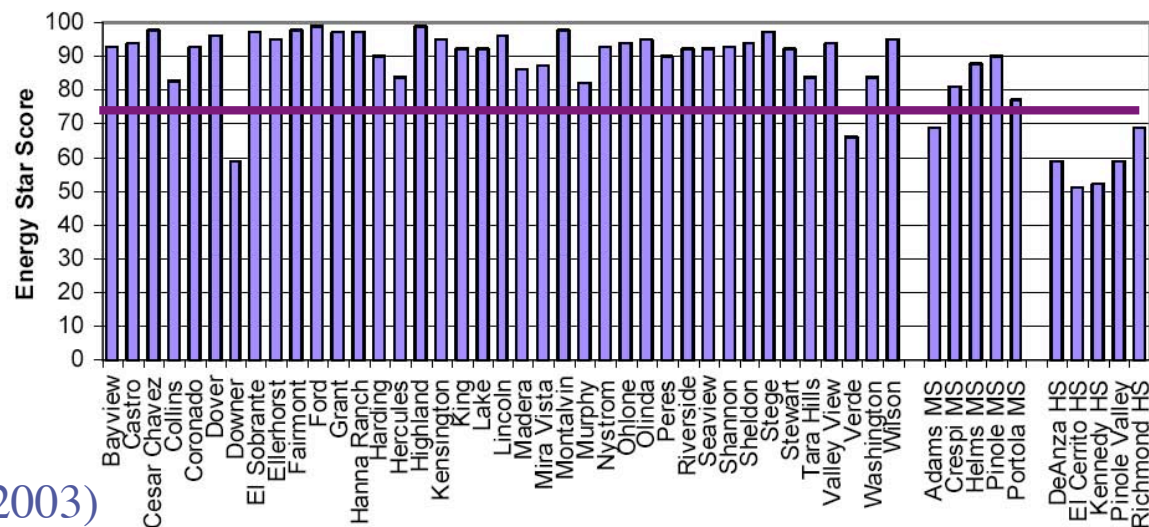
Source: NHTSA

# Choice of Benchmark Determines “Results” & Actions

Average Index of  
Various Indicators  
(energy/student,  
energy/sf, etc.)



ENERGY STAR  
Score  
(75 = “passing”)



Source: Norford,  
Palomera-Arias, and Ramsey (2003)

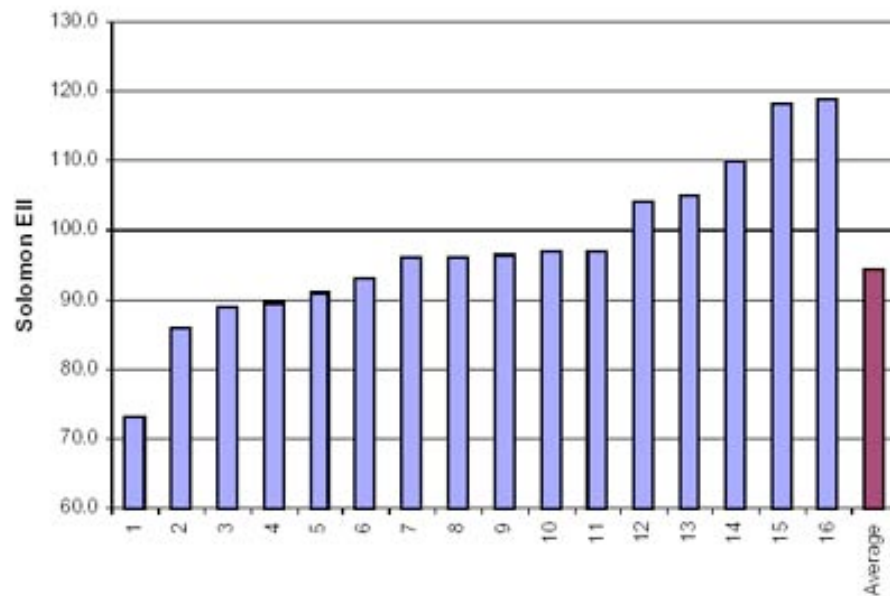
# Approaches to Benchmarking

- ◆ Point-estimates (vs. population avg.)
- ◆ Statistical (bell curve; vs. population)
- ◆ Point-based (vs. best practice)
- ◆ Model-based (actual vs. efficient)
- ◆ Standardized (vs. test procedure)

Scope: self-referential; enterprise; stock

Timeframe: historic trends vs. current

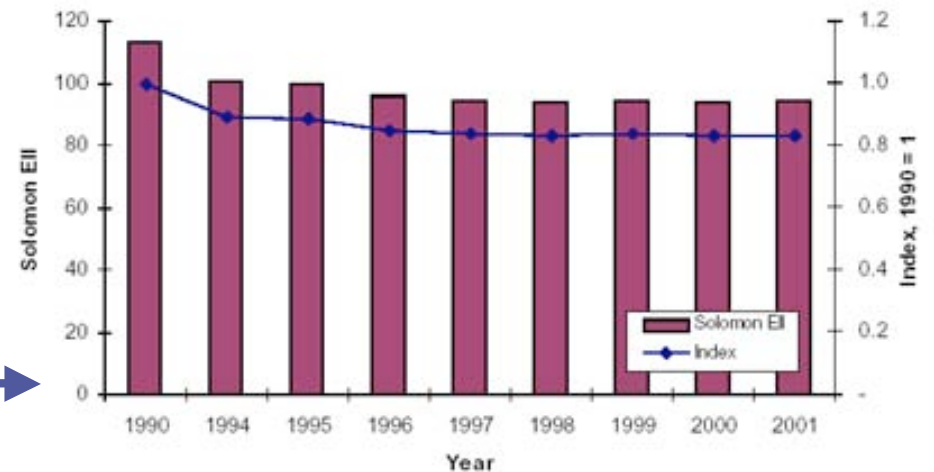
# Lateral & Longitudinal: e.g. Canadian Oil Refineries



Solomon Energy Intensity Index of Participating Individual Refin  
Source: CIEEDAC, 2002.

Following “fleet-wide”  
trends over time

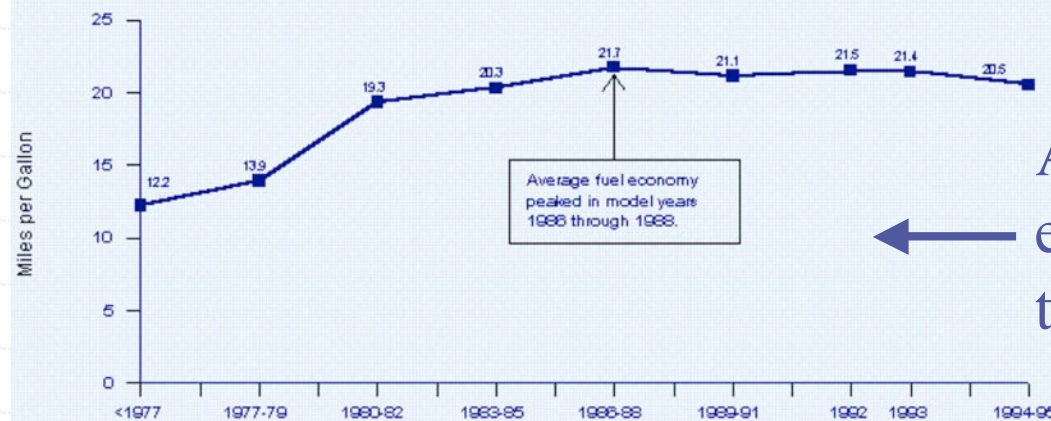
Comparing “peers” at  
one point in time



Average Refinery Energy Intensity based on a composite of Solomon EII for all known refineries.<sup>4</sup>

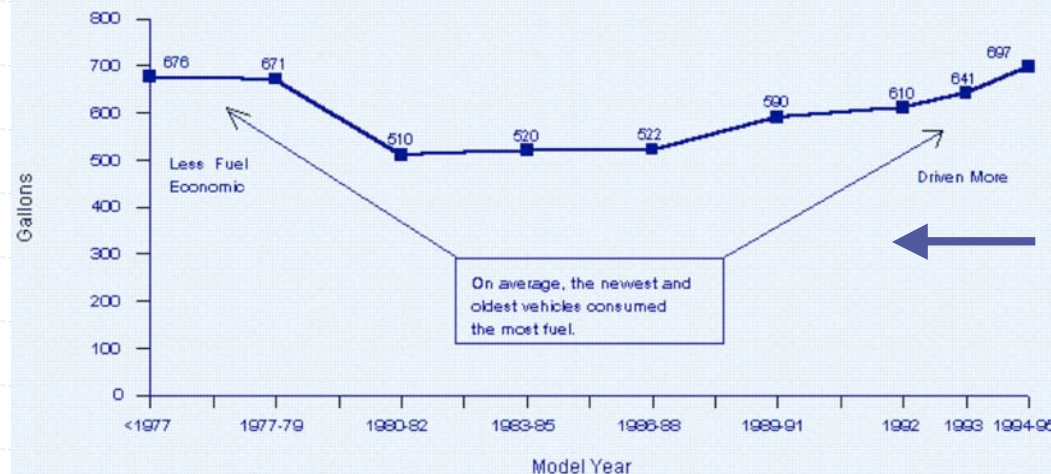
# Decide What is Important Before Benchmarking

Figure 4.1 Average Fuel Economy of Residential Vehicles for Model Years Through 1995



Average US fuel economy increasing, then flat

Figure 4.9 Average Residential Vehicle Fuel Consumption per Vehicle for Model Years Through 1995



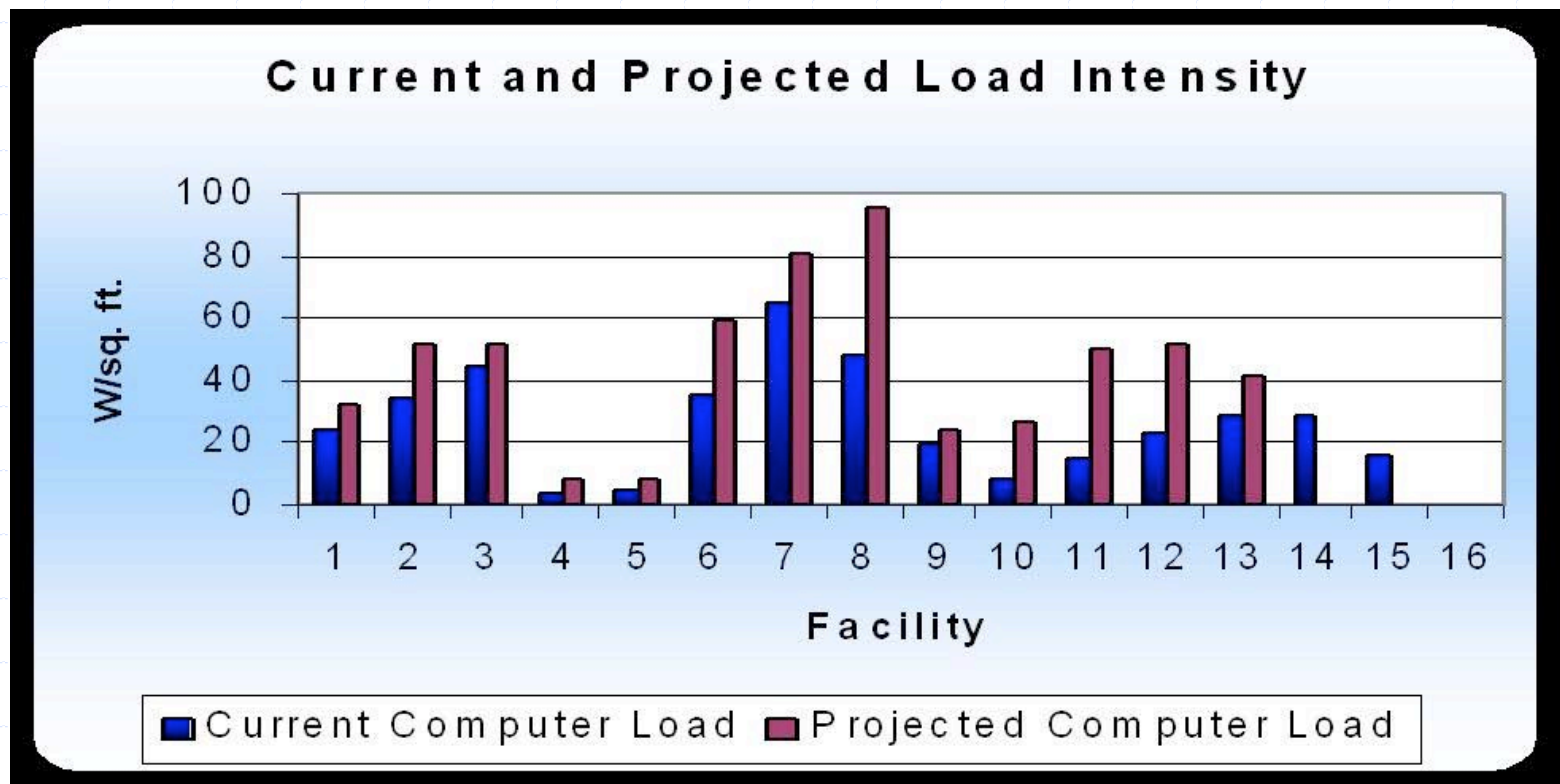
Average US vehicle fuel use declining then rising

Source: DOE/EIA

# Benchmarks Can Provide a “Reality Check”: Data Centers

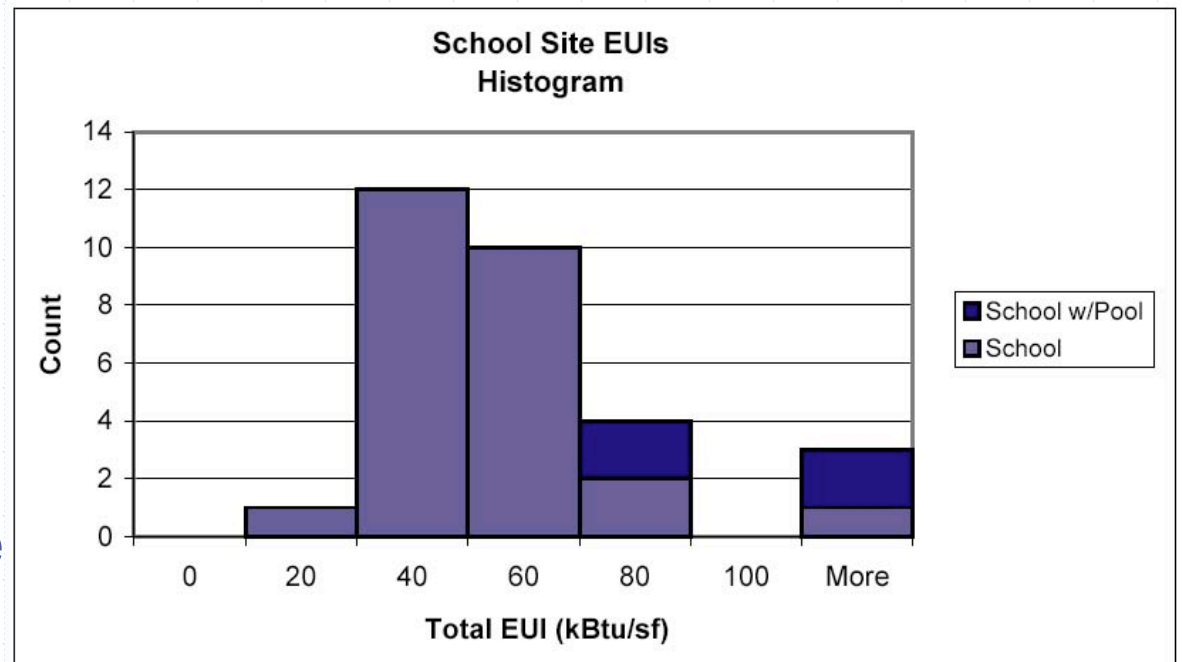
California Data Center owners claim a need of 250 W/ft<sup>2</sup>

Real data benchmarks the actual need between 10 and 100.



# Caveats & Pitfalls

- ◆ Intensity does not equal efficiency
- ◆ Hard to avoid apples-and-oranges comparisons (want energy per unit of service)
- ◆ Normalization
  - √ weather
  - √ floor area
  - √ schedule
  - √ plug loads
  - √ indoor conditions
  - √ energy price



# Examples from Hawaii

## ◆ Schools

- √ 32 Schools
- √ Average EUI: 5.9 kWh/ft<sup>2</sup>-year
- √ Range: 3.05 - 11.52 kWh/ft<sup>2</sup>-year

## ◆ Banks

- √ 49 Branches
- √ Average EUI: 20.07 kWh/ft<sup>2</sup>-year
- √ Range: 7.96 - 36.40 kWh/ft<sup>2</sup>-year

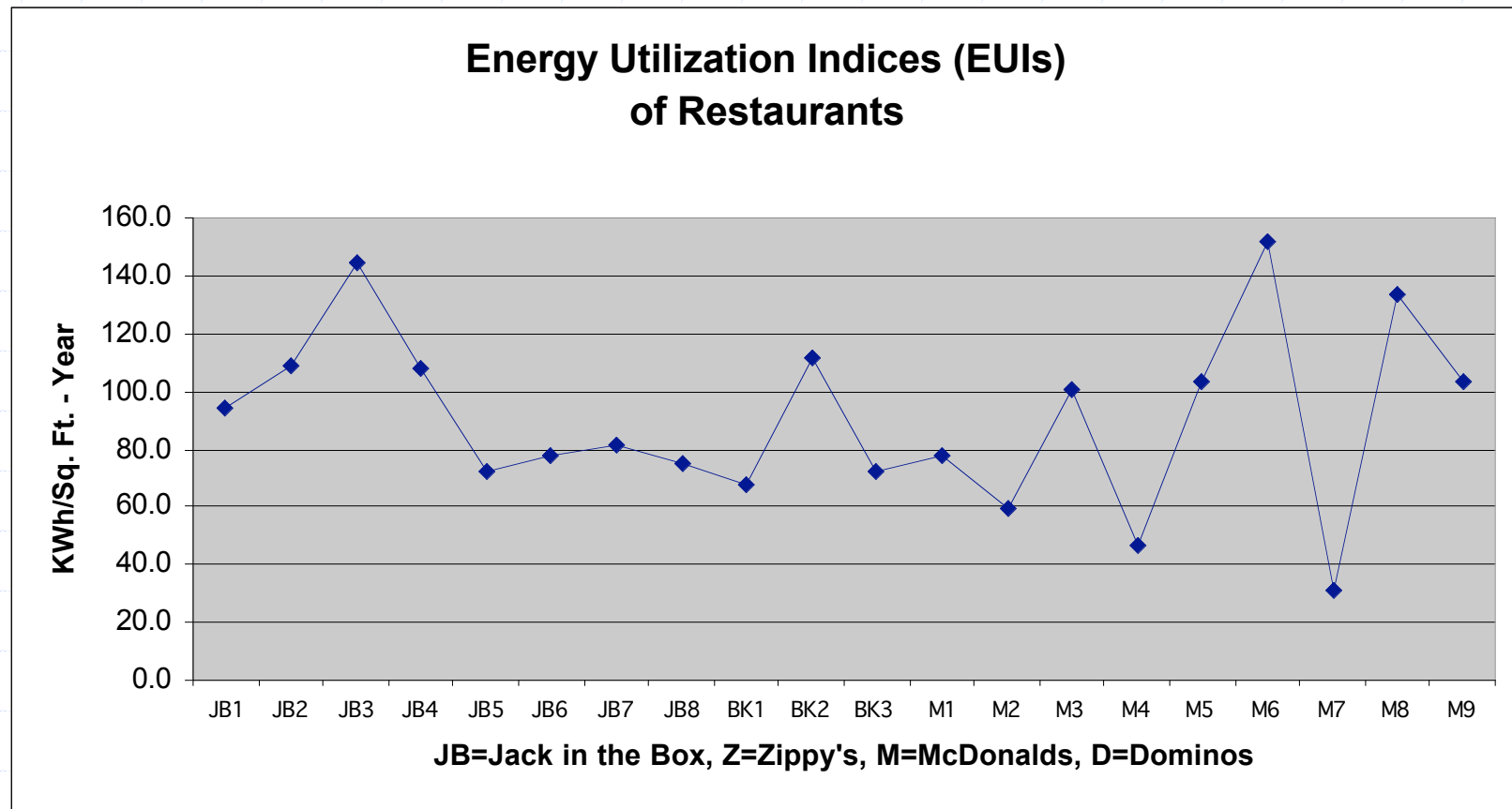
Source: HECO, Thomas D. Van Liew

# Hawaii Commercial Buildings Benchmarking Study

- ◆ Offices: **22.82 kWh/ft<sup>2</sup>-y**
- ◆ Lodging: **16.14 kWh/ft<sup>2</sup>-y**
- ◆ Restaurants: **52.88 kWh/ft<sup>2</sup>-y**
- ◆ Grocery Store: **53.05 kWh/ft<sup>2</sup>-y**
- ◆ Education: **9.00 kWh/ft<sup>2</sup>-y**
- ◆ University of Hawaii: **13.82 kWh/ft<sup>2</sup>-y**
- ◆ Health Care: **24.83 kWh/ft<sup>2</sup>-y**
- ◆ Retail: **25.50 kWh/ft<sup>2</sup>-y**
- ◆ Apartments: **10.11 kWh/ kWh/ft<sup>2</sup>-y**
- ◆ Warehouse: **6.76 kWh/ kWh/ft<sup>2</sup>-y**
- ◆ Miscellaneous: **12.09 kWh/ kWh/ft<sup>2</sup>-y**

Source: HECO, Thomas D. Van Liew

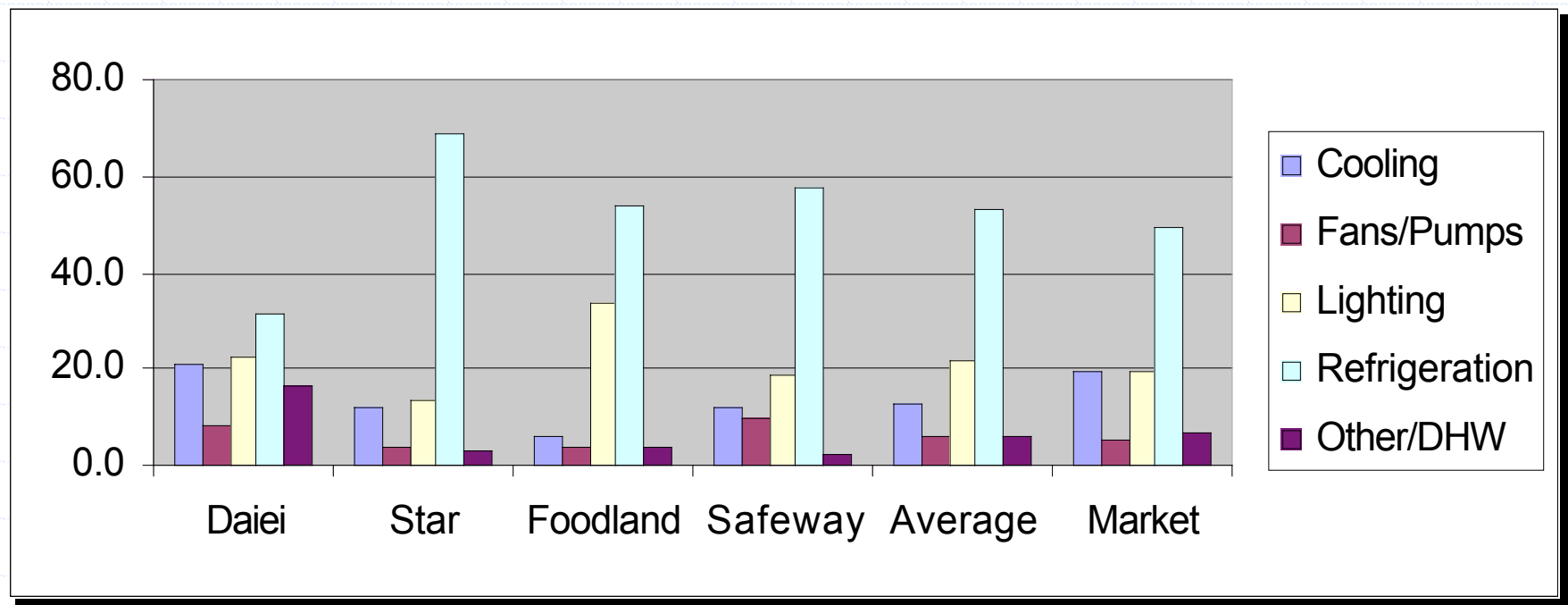
# Fast Food Restaurant EUIs: Hawaii



Source: HECO, Thomas D. Van Liew

# Grocery Store Energy Intensities

Hawaii Average = 70.9 kWh/ft<sup>2</sup>-year



Source: HECO, Thomas D. Van Liew

# Energy Intensities

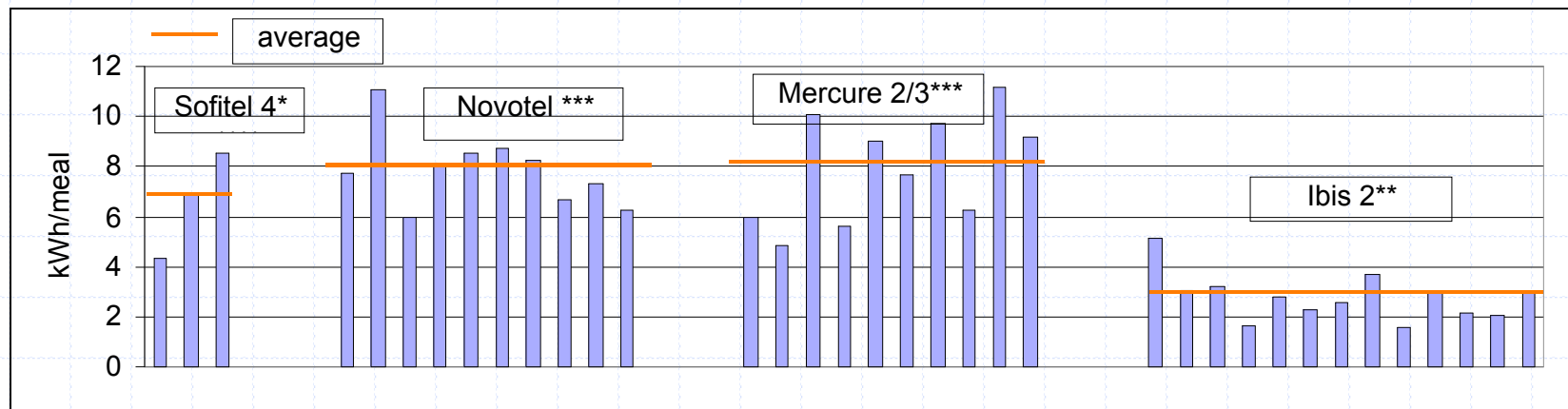
## Energy per meal for 36 hotels, France

Std. Dev. 34%

27%

19%

32%

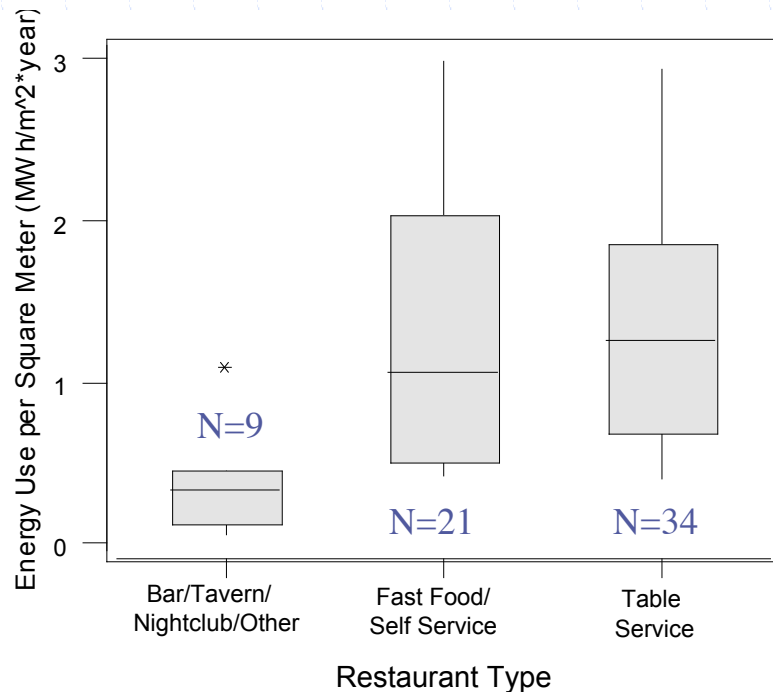


category of hotels	conservation kWh/meal	cooking kWh/meal	dishwashing kWh/meal	total kWh/meal	standard deviation
2**	0.44	2.08	0.25	2.77	0.94
2**/3***	3.81	3.89	0.25	7.95	2.18
3***	3.67	3.99	0.21	7.86	1.47
4****	2.53	3.92	0.13	6.58	2.13

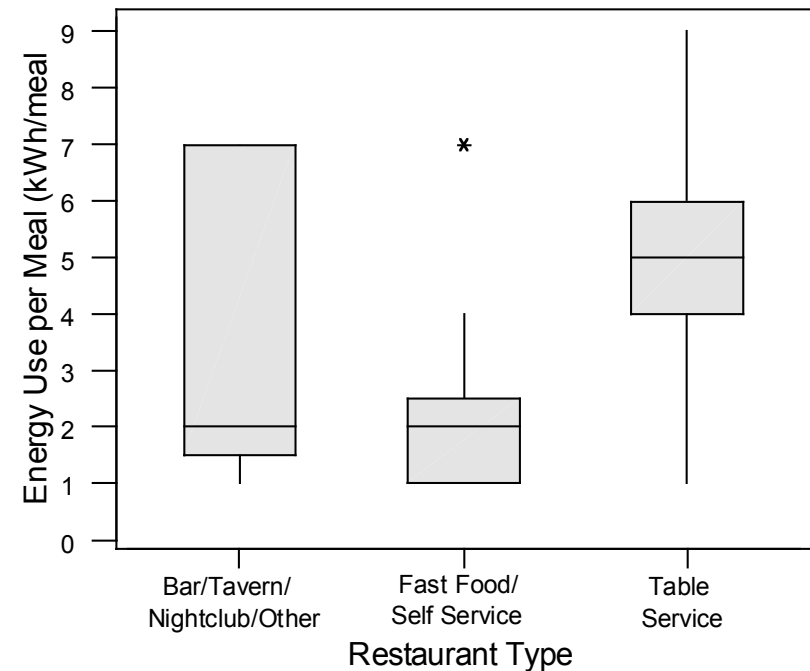
Source: Le Strat et al., (1999)

# Choice of Indicator is Key

Energy per unit floor area



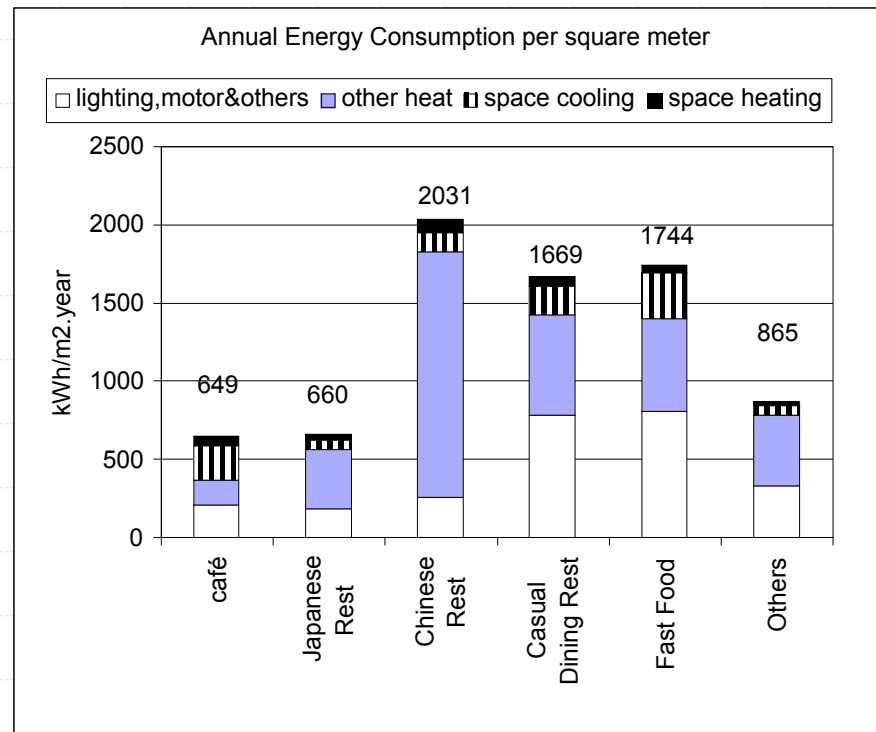
Energy per meal



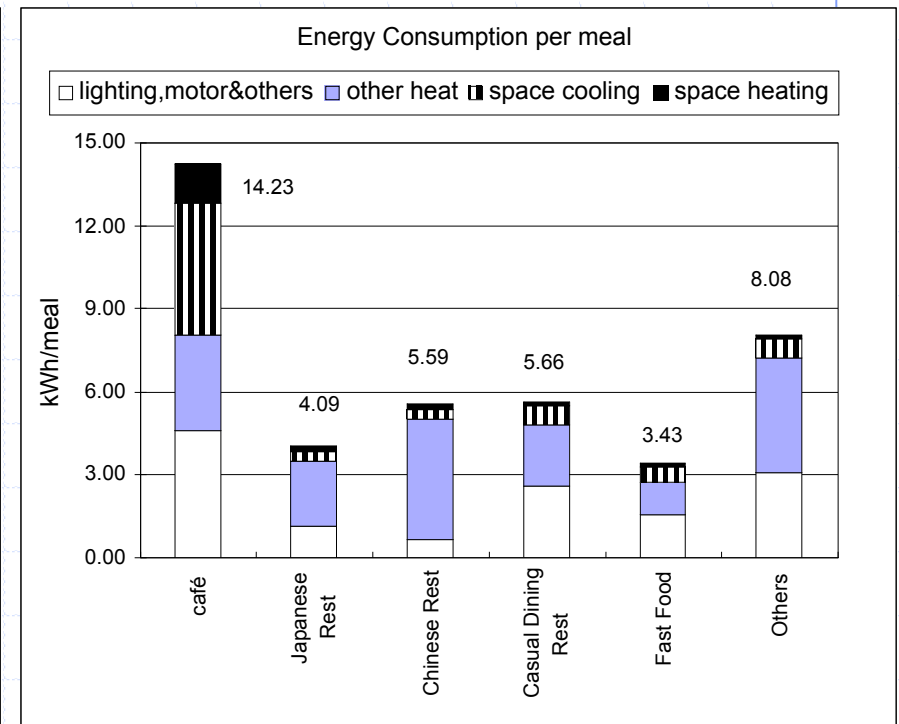
Source: 1996 California Commercial End Use Survey  
(Restaurant energy)

# Choice of Indicator is Key

## Energy per unit floor area

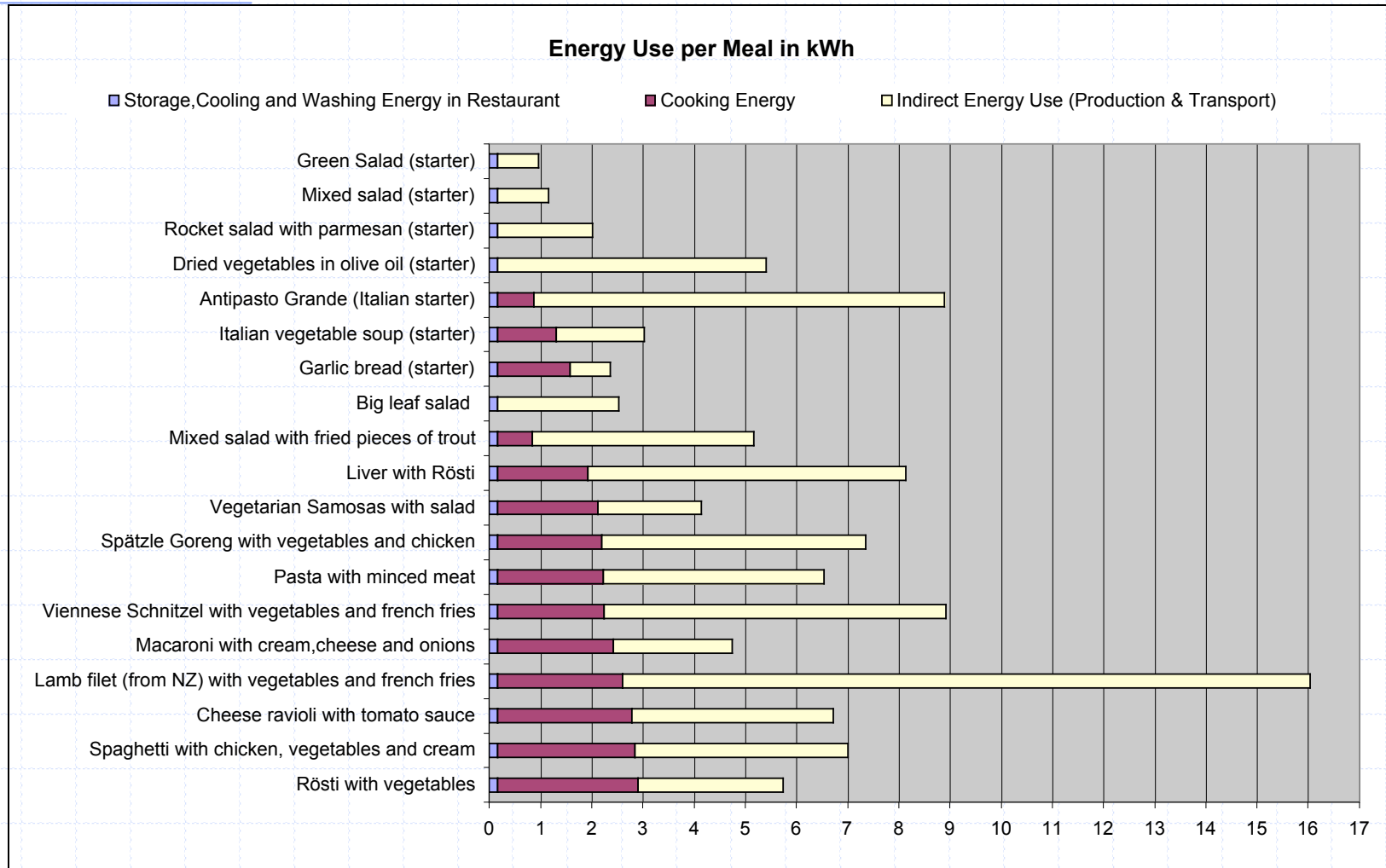


## Energy per meal



Source: The Energy Data and Modeling Center, 2001

# Beyond “Apples & Oranges”: Pippins and Granny Smiths



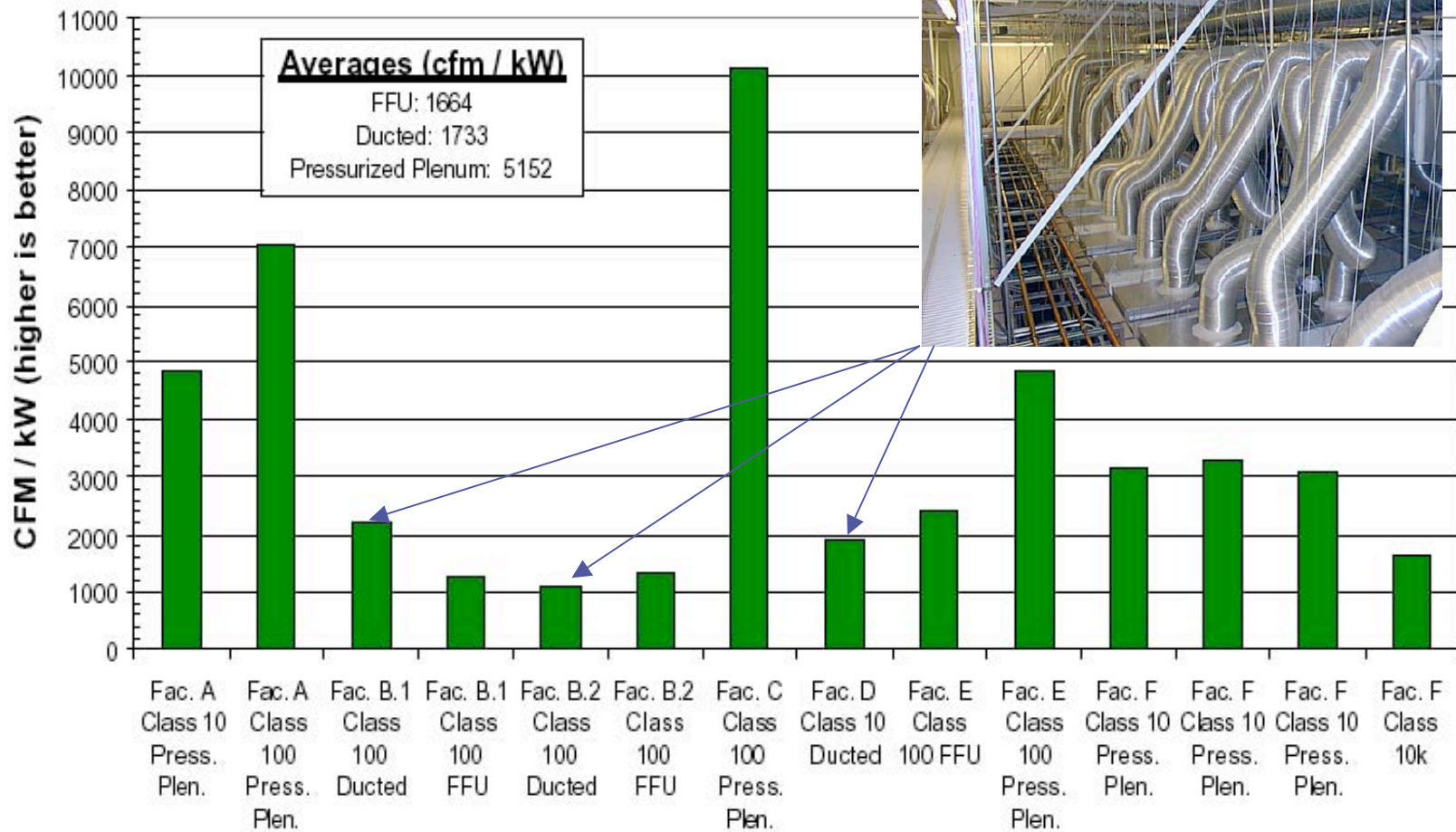
Data for Switzerland. Source: Balmer and Hintermann, 2000

# Cleanroom Energy Metrics

•Recirculation air handler efficiency	•cfm/kW
•Makeup air handler efficiency	•cfm/kW
•Annual energy cost per cleanroom square foot	•\$/ft <sup>2</sup>
•Annual fuel usage	•MBtu/ft <sup>2</sup> -yr
•Annual electricity usage	•kWh/ft <sup>2</sup> -yr
•Annual energy usage	•MBtu/ft <sup>2</sup> -yr
•Makeup air	•cfm/ft <sup>2</sup>
•Recirculation air	•cfm/ft <sup>2</sup> or ach
•Chiller efficiency	•kW/ton
•Tower efficiency	•kW/ton
•Condenser water pump efficiency	•kW/ton
•Chilled water pump efficiency	•kW/ton
•Total chilled-water plant efficiency	•kW/ton
•Hot water pumping efficiency	•kW/MBtu
•Cooling load density	•ft <sup>2</sup> /ton

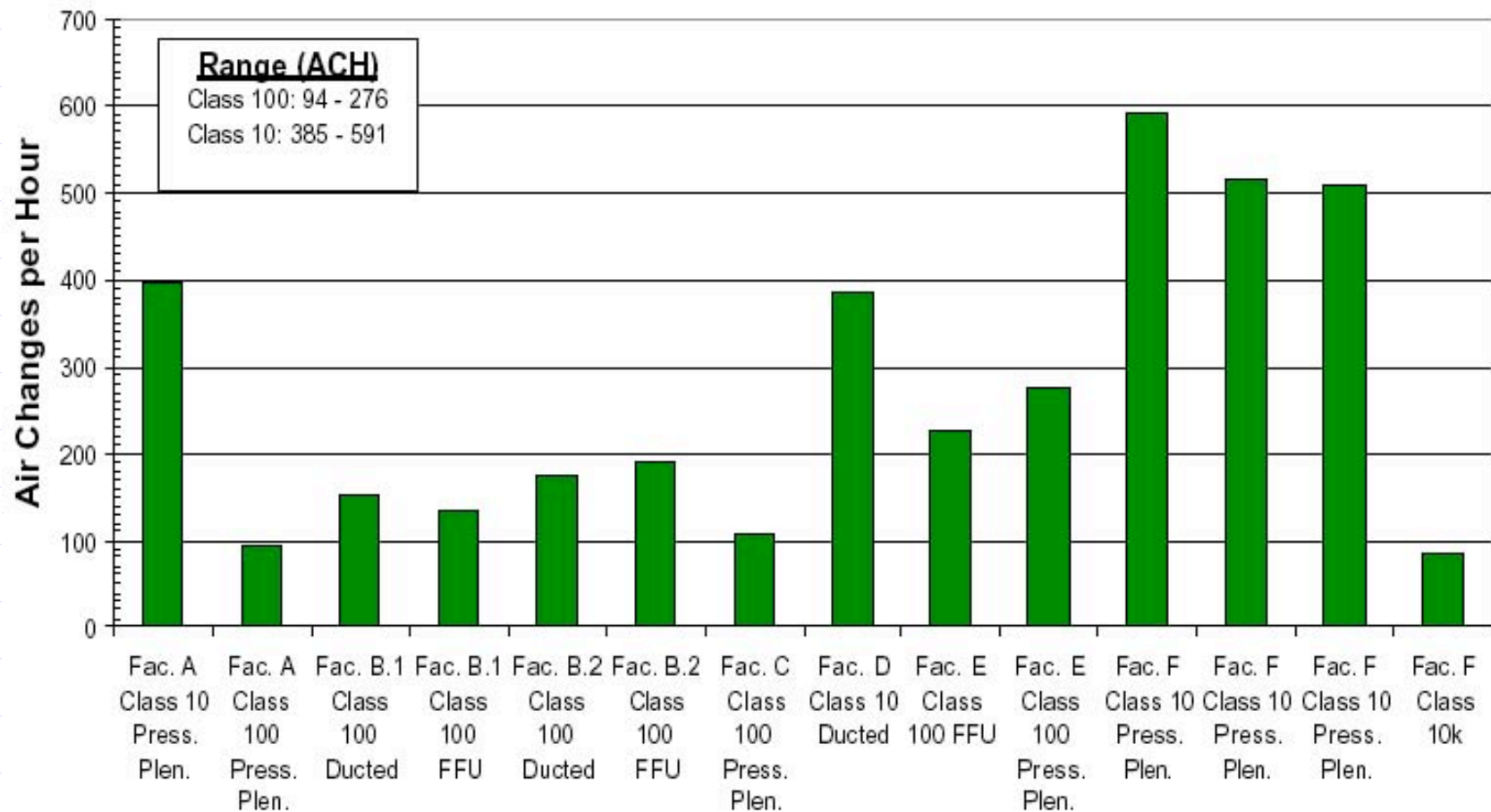
Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

# Delivery of Service Levels



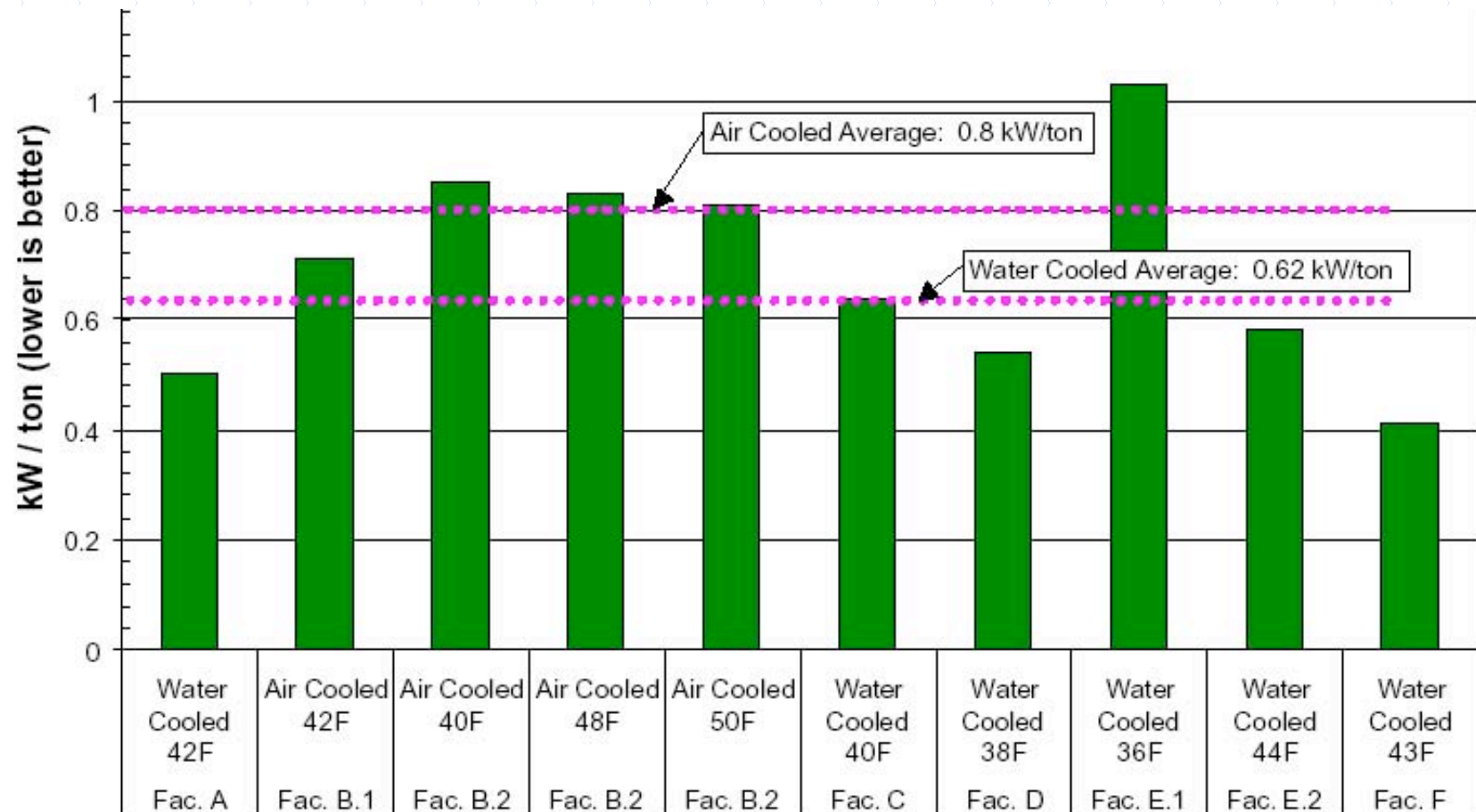
Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

# Some “Energy” Benchmarks Don’t Even Include Energy



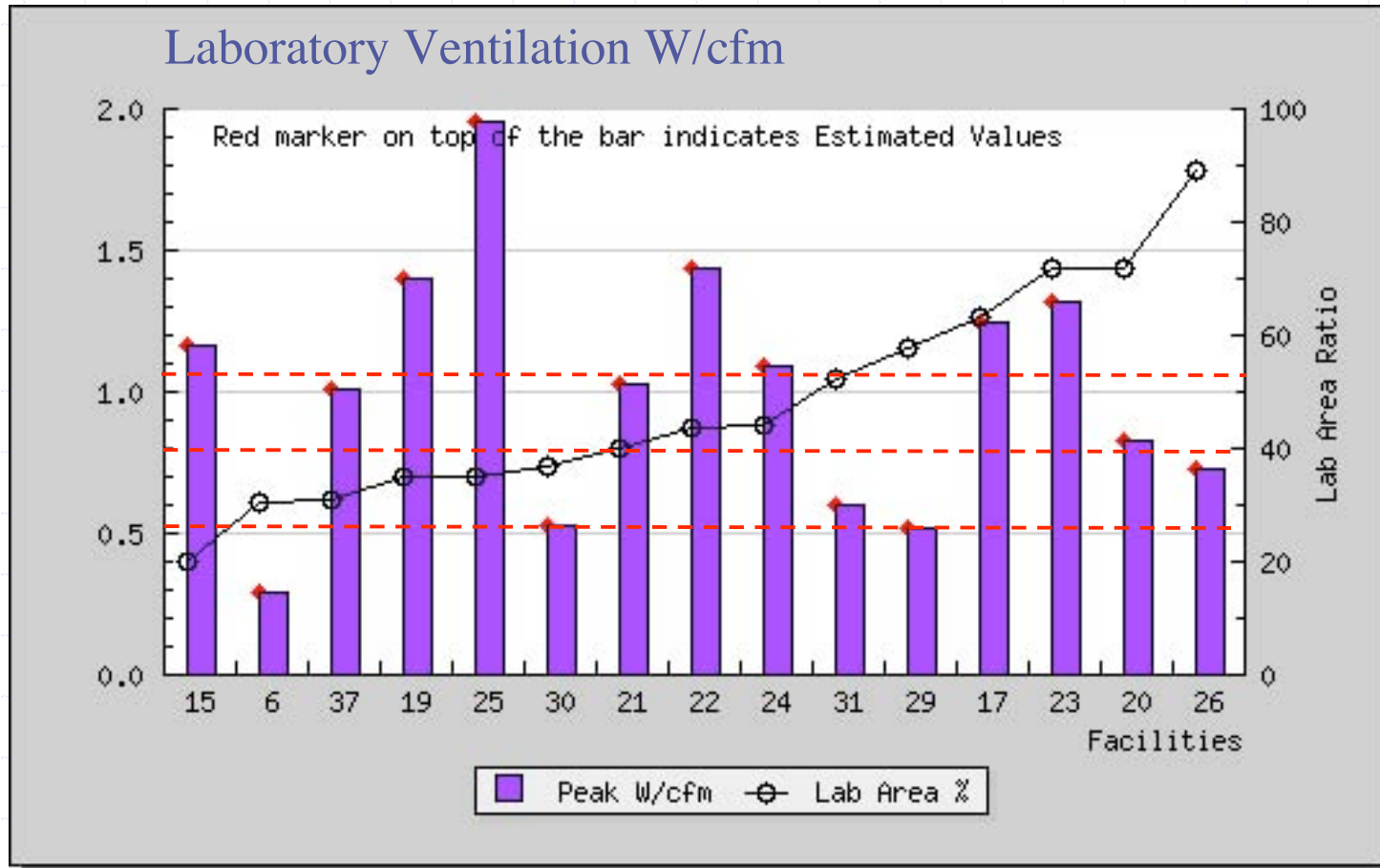
Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

# Cleanroom Chiller Efficiencies



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

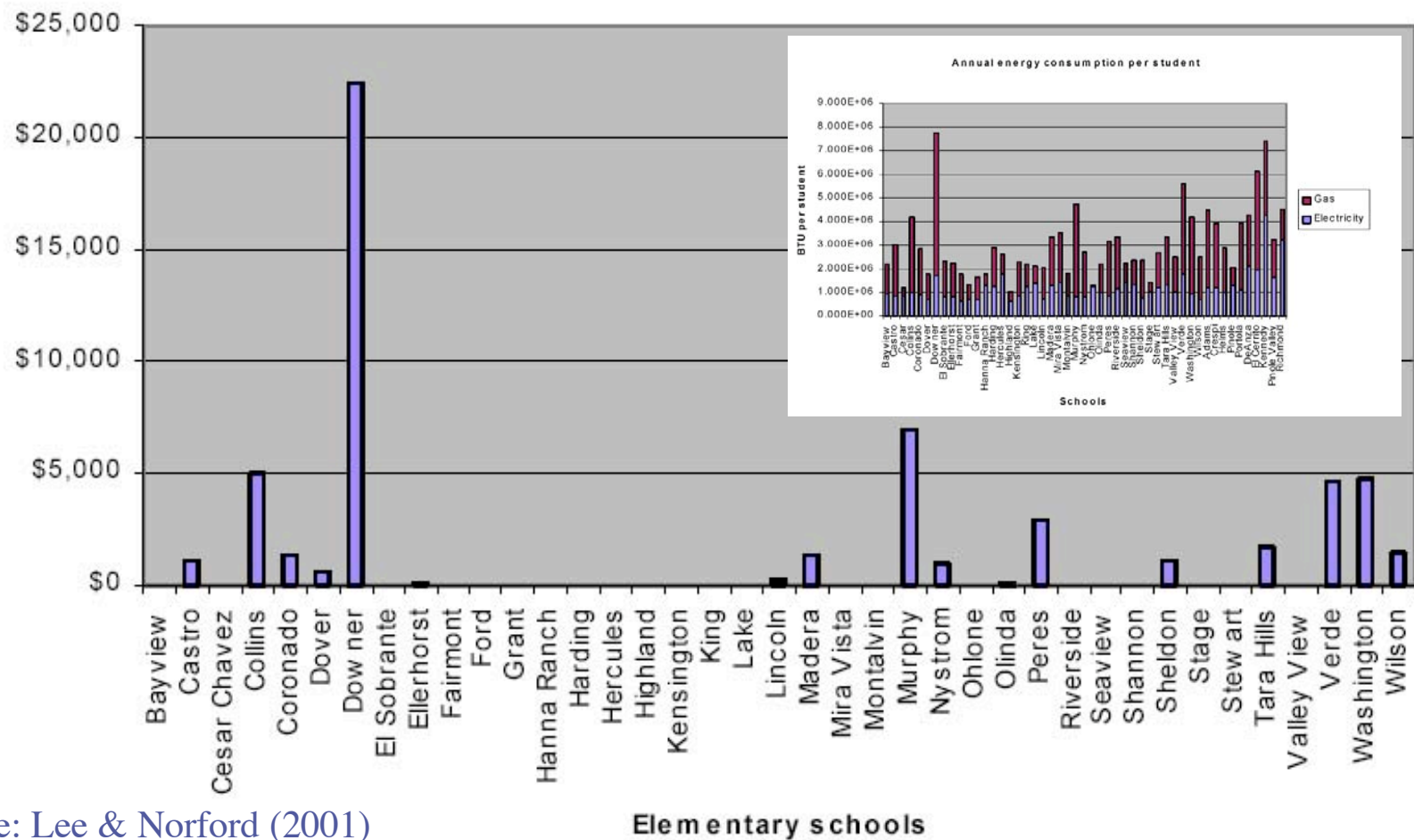
# From Benchmarking to Best Practices



Standard, good, better benchmarks as defined in  
"How-low Can You go: Low-Pressure Drop Laboratory Design"  
by Dale Sartor and John Weale, ASHRAE Journal

# Benchmarks as Screening Tool

Annual gas expenditure saving if brought to the median value



Source: Lee & Norford (2001)



ENERGY STAR® SEARCH  Go

YOUR HOME CONTRIBUTES TO  
THE QUALITY OF OUR ENVIRONMENT

print  
view

PRODUCTS

HOME  
IMPROVEMENT

NEW HOMES

BUSINESS  
IMPROVEMENT

PARTNER  
RESOURCES

+ WHAT IS ENERGY STAR?  
+ NEWS ROOM

[Home](#) > [Home Improvement](#) > Home Energy Yardstick

Home Energy  
Yardstick

[Home Energy  
Advisor](#)

Improve Your  
Home

+ [Home Sealing](#)  
+ [Heating &  
Cooling](#)

[Common Home  
Improvements](#)

## Home Energy Performance Results

### Energy Performance

**Your score is 7.7 out of 10**

This means that about **23%** of U.S. homes use less energy than yours.

Improving your score from **7.7** to **8.7** is approximately a 12% reduction in energy use and could save you up to **\$270** a year on energy costs.

### Environmental Performance

Annual pollution from energy use in your home is equivalent to the emissions of **1.9** cars. Improving your score from **7.7** to **8.7** would reduce your emissions by 12%.

About Your Home & Energy Use [\[Edit Info\]](#)

### About Your Home

Zip Code: 96801

People Living in Home: 4

Square Footage of Home: 2000

Home Built: 2000s

Electric Well Pump? No

Heating Degree Days: 0

Cooling Degree Days: 4401

[Printable](#)

### Improving your Performance

To improve your score and save energy you need help to identify the most cost effective improvements for your home. Here are some suggestions:

[Use the Home Energy Advisor to identify the five most cost effective ways for you to save money and energy.](#)

[Locate an Energy Management Consultant](#)

[Find ENERGY STAR labeled products for your home.](#)

# ENERGY STAR Building Label

## Normalized Benchmark Data

	ENERGY STAR	Your Building
Benchmarking Score:	75	77
Energy Intensity:		
Site (kBtu/ft <sup>2</sup> -yr):	57	55
Source (kBtu/ft <sup>2</sup> -yr):	171	166
Emissions:		
CO <sub>2</sub> (1000 lbs/yr):	21,154	20,527
SO <sub>2</sub> (1000 lbs/yr):	140	136
NO <sub>x</sub> (1000 lbs/yr):	34	33
Energy Cost:		
(\$):	842,161	817,189
(\$/ft <sup>2</sup> -yr):	1.33	1.29

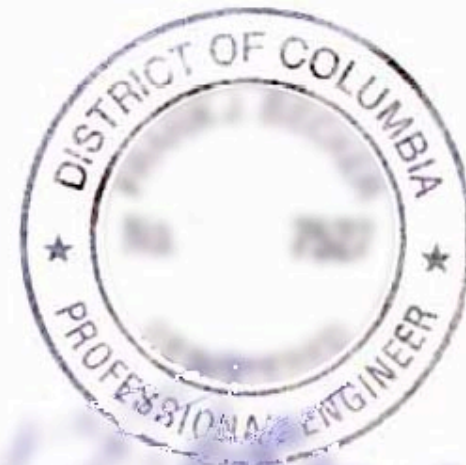
## Indoor Environment Criteria

INDOOR AIR POLLUTANTS CONTROLLED?  
ADEQUATE VENTILATION PROVIDED?  
THERMAL CONDITIONS MET?  
ADEQUATE ILLUMINATION PROVIDED?

PASS  
PASS  
PASS  
PASS

## Professional Verification

Jason Jeter, Professional Engineer  
Jeter, James and Jones Engineering  
Street Address: 1701 Irving Street  
City, State: Washington, DC 20036  
Phone Number: 202-123-1234



Professional Engineer Stamp

Based on the conditions observed at the time of my visit to this building, I certify that this statement is accurate.

# Labs21 Benchmarking Tool

## Data Input

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: http://www.dc.lbl.gov/Labs21/StepThreeP3.php

**LABS FOR THE 21ST CENTURY**

**benchmarking**

step one of four - login  
 step two of four - enter facility name and year of data  
**step three of four - enter data for the facility**  
 step four of four - review / edit entered data

\* Indicates Required Input

Data / Facility Information	
User	LBNL
Organization	Lawrence Berkeley National Laboratory
Facility chosen	Bldg2-AdvancedMaterialLab
Year chosen	2001

General Facility	
Street Address*	One Cyclotron Road
Location*	Berkeley, CA
Zip Code (5 digit)*	94720
Lab Use*	Research/Development
Lab Type*	Combination/Others
Lab Category*	Combination/Others
Number of Building(s)	1
Gross Area (sq. ft.)*	85761

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: http://www.dc.lbl.gov/Labs21/StepThreeP3.php

Energy Use		Measured	Estimated
Annual Energy Utility Cost (\$)*	231000	<input checked="" type="radio"/>	<input type="radio"/>
Annual Heating Energy (therms)*	124800	<input checked="" type="radio"/>	<input type="radio"/>
Does facility use CHP (Cogen) system?	No		
<b>Annual Electric Use (kWh)</b>			
Total*	2526000	<input checked="" type="radio"/>	<input type="radio"/>
Ventilation	1010000	<input type="radio"/>	<input checked="" type="radio"/>
Cooling Plant (including campus chilled water, if any)	298000	<input type="radio"/>	<input checked="" type="radio"/>
Lighting	460000	<input type="radio"/>	<input checked="" type="radio"/>
Process/plug	1150000	<input type="radio"/>	<input checked="" type="radio"/>
<b>Peak Demand (kW)</b>			
Total*	478	<input checked="" type="radio"/>	<input type="radio"/>
Ventilation	0	<input type="radio"/>	<input checked="" type="radio"/>
Cooling Plant (including campus chilled water, if any)	0	<input type="radio"/>	<input checked="" type="radio"/>
Lighting	0	<input type="radio"/>	<input checked="" type="radio"/>
Process/plug	0	<input type="radio"/>	<input checked="" type="radio"/>

System		Measured	Estimated
Peak Cooling Load (Tons)	0	<input type="radio"/>	<input checked="" type="radio"/>
Average Cooling Load (Tons) (Total annual cooling ton-hours divided by 8760)	0	<input type="radio"/>	<input checked="" type="radio"/>
Cooling Plant Capacity (Tons)	500	<input checked="" type="radio"/>	<input type="radio"/>
Peak CFM (Sum of exhaust, supply, and recirculating fans)	0	<input type="radio"/>	<input checked="" type="radio"/>
Average CFM (Sum of exhaust, supply, and recirculating fans)	0	<input type="radio"/>	<input checked="" type="radio"/>

# Labs21 Benchmarking Tool Analysis

Benchmarking Labs for the 21st Century Web Toolkit - Microsoft Internet Explorer

Address: http://www.dc.lbl.gov/Labs21/CompareData.php?UserID=2

**LABS FOR THE 21ST CENTURY**

**benchmarking**

Choose Metrics and Filtering Criteria

[More Information](#)

User: **LBNL**  
Organization: **Lawrence Berkeley National Laboratory**

Please specify the metric criteria -

System: Total Building  
Energy / Efficiency Metric: BTU/sf-yr (site)

Please specify the filtering criteria -

1. Lab Area / Gross Area ratio  
is greater than or equal to 0.00 and is less than or equal to 0.99

2. Occupancy  
☐ Standard ( $\leq 14$  hours)  
☐ High ( $> 14$  hours)  
☒ Both (all data)

3. Climate [Climate Code, Climate Type, Representative City]  
([To view the map of climatic distribution](#))

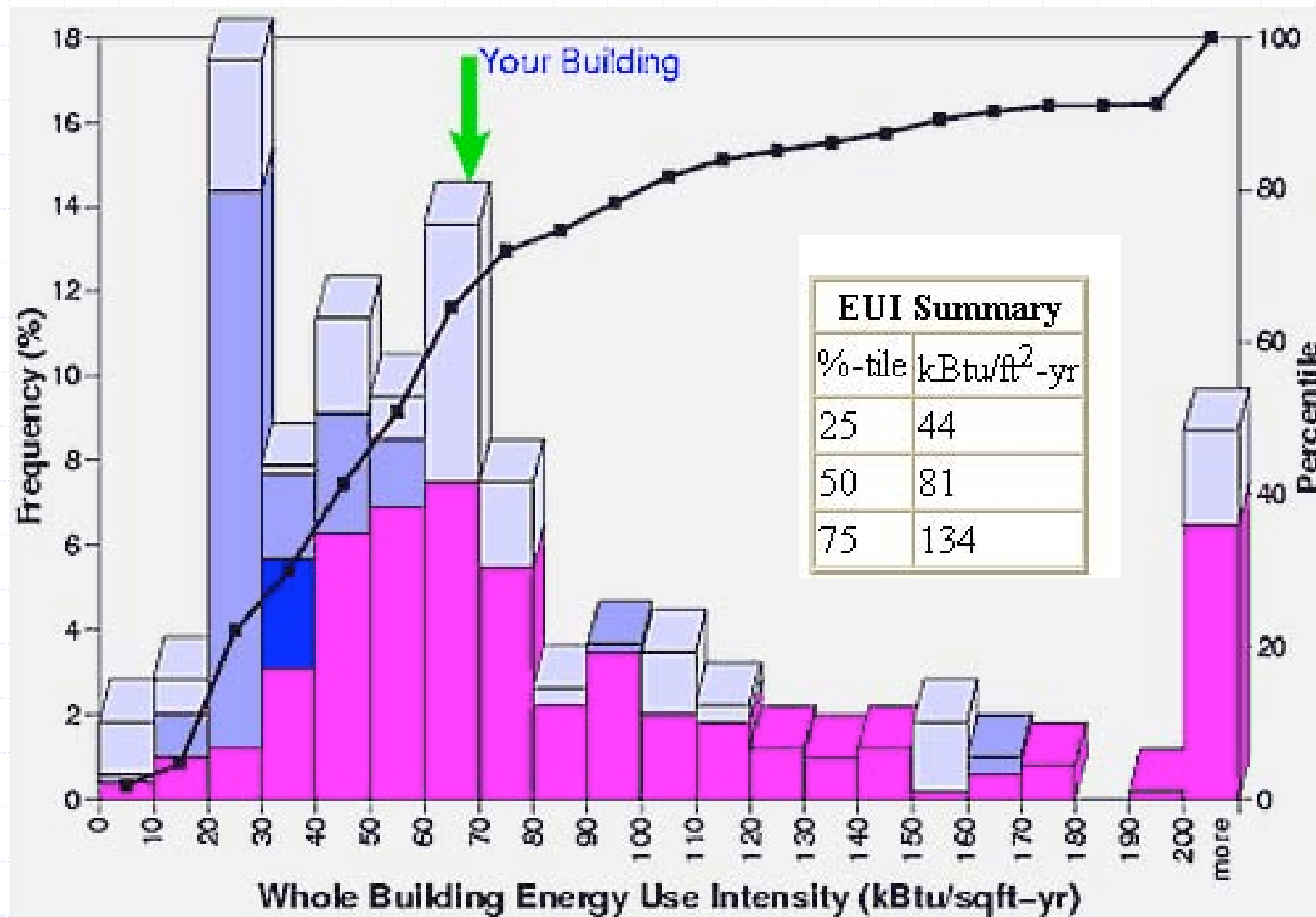
<input checked="" type="checkbox"/> 1A, <b>Very Hot - Humid</b> (Miami, FL)	<input checked="" type="checkbox"/> 2A, <b>Hot - Humid</b> (Houston, TX)
<input checked="" type="checkbox"/> 2B, <b>Hot - Dry</b> (Phoenix, AZ)	<input checked="" type="checkbox"/> 3A, <b>Warm - Humid</b> (Memphis, TN)
<input checked="" type="checkbox"/> 3B, <b>Warm - Dry</b> (El Paso, TX)	<input checked="" type="checkbox"/> 3C, <b>Warm - Marine</b> (San Francisco, CA)
<input checked="" type="checkbox"/> 4A, <b>Mixed - Humid</b> (Baltimore, MD)	<input checked="" type="checkbox"/> 4B, <b>Mixed - Dry</b> (Albuquerque, NM)
<input checked="" type="checkbox"/> 4C, <b>Mixed - Marine</b> (Salem, OR)	<input checked="" type="checkbox"/> 5A, <b>Cool - Humid</b> (Chicago, IL)
<input checked="" type="checkbox"/> 5B, <b>Cool - Dry</b> (Bosie, ID)	<input checked="" type="checkbox"/> 6A, <b>Cold - Humid</b> (Burlington, VT)
<input checked="" type="checkbox"/> 6B, <b>Cold - Dry</b> (Helena, MT)	<input checked="" type="checkbox"/> 7, <b>Very Cold</b> (Duluth, MN)
<input checked="" type="checkbox"/> 8, <b>Subarctic</b> (Fairbanks, AK)	

[Reset Values](#) [Continue...](#)

Done



# Cal-ARCH: Web-based Benchmarking



# Capturing Benchmarks with Design Intent Documentation

**Design Intent Tool 1.0 - [LBNL Project Template for Laboratories]**

File

Introduction | Manage Project Files | Manage Template Files | User Guide | Feedback | Help | Web Home Page

Design Intent Document | Owner's Goals & Project Info | Team Contact Info | Reports

**DESIGN INTENT TOOL**  
VERSION 1.0

Design Intent Tool 1.0  
Project Name: LBNL Project Template for Laboratories  
Owner: LBNL  
Today's Date: 08-20-2002

Select Design Area  
+/- Add/Remove

- ☒ General
- ☐ Architectural: Loads
- ☐ Mechanical: Ventilation System
- ☐ Mechanical: Chiller Plant
- ☐ Mechanical: Heating Plant
- ☐ Electrical: Lighting System
- ☐ Electrical: Distribution System
- ☐ Electrical: Renewable/Distributed
- ☐ Process: Process/Plug Loads
- ☐ Operations and Maintenance

Design Area Description  
This area includes whole-building information or information pertaining to multiple design areas.

Select Objective  
+/- Details Click this button to add, remove or edit Objectives for this project

Objective Name	Objective Description
Achieve high overall energy efficiency	Energy efficiency is low energy consumption to accomplish a given task. High overall efficiency is low whole-building energy use (electric energy, peak electric power demand, natural gas, and any other fuels) to provide a laboratory building of a certain

Strategies  
+/- Details Click this button to add, remove or edit Strategies for the Objective selected above.

Index	Strategy Name	Strategy Description
1	Exceed Title 24 requirement by factor of 2.5 (energy use 40% of Title 24 budget)	Energy code requirements can typically be easily outperformed. Such requirements make a convenient baseline against which simulated performance can be compared. Title 24 is California's State Energy Code. Buildings can comply with the Code either by the prescriptive or
2	Achieve LEED Platinum rating	The Leadership in Energy and Environmental Design (LEED) system was created by the U.S. Green Building Council to comprehensively rate buildings for their environmental impact and sustainability. Platinum is the highest rating.
3	Minimize life-cycle cost	The life-cycle cost of a building is its total cost over its entire life, including design, construction, operation, maintenance, renovation, and decommissioning; future costs are discounted to present value for comparison. Minimizing life-cycle costs usually results in higher first

Metrics  
Assessment Records Click this button to view and edit Assessment Records for the Objective selected above.

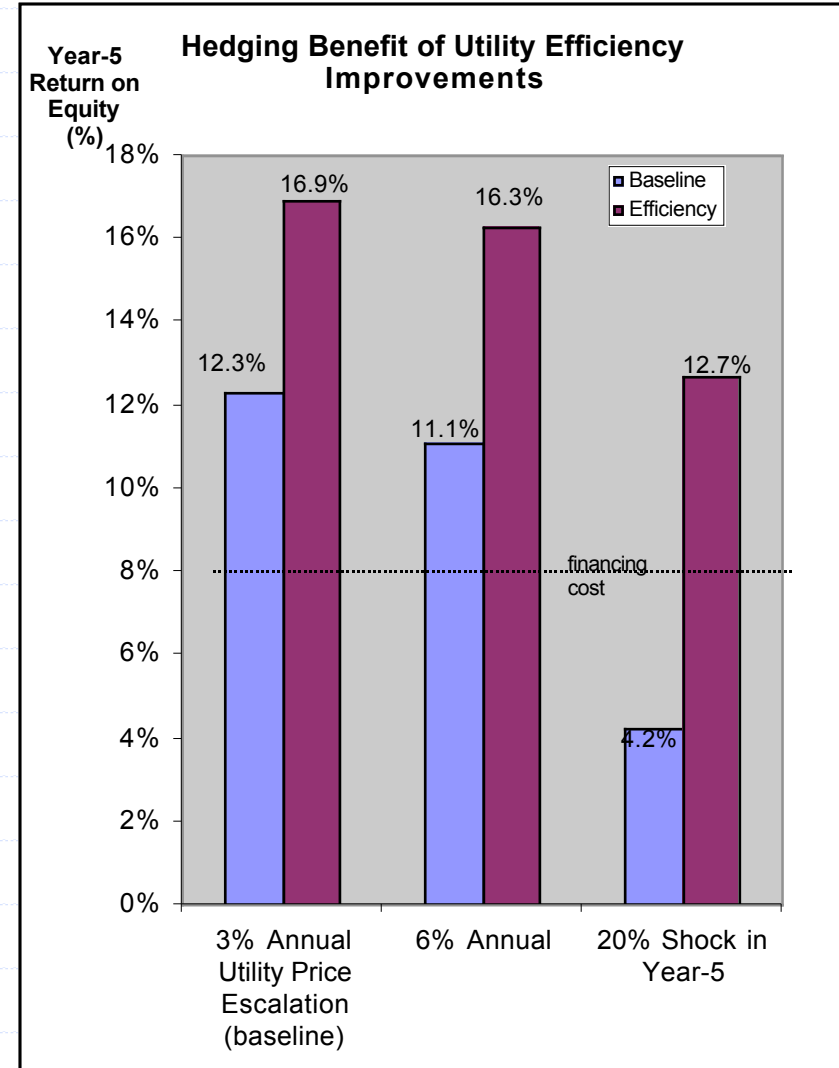
Index	Metric Name	Metric Description	Target	Units
1	Total annual kWh/sf	Whole-building electric energy use per gross square foot of building. From building electric meter.		
2	Annual source BTU/sf (combined gas and electric)	Whole-building total energy use per gross square foot of building. Source BTU/sf is calculated using XXXX BTU/kWh of electricity and a		

# Approach

- ◆ Decide how benchmark is to be used
  - √ Choose type(s) of benchmarks
  - √ Define “indicators”
  - √ Be creative
- ◆ Measurement plan
- ◆ Clear definitions (e.g. “floor area”)
- ◆ Collect data (privacy issues)
- ◆ Establish filters & normalization methods
- ◆ Learn from “outliers”

# Needs

- ◆ Considerable unmet need for benchmarking presentations that bridge the “physical” and “financial”
- ◆ More focus on component or end-use benchmarking
- ◆ Growing importance of peak demand

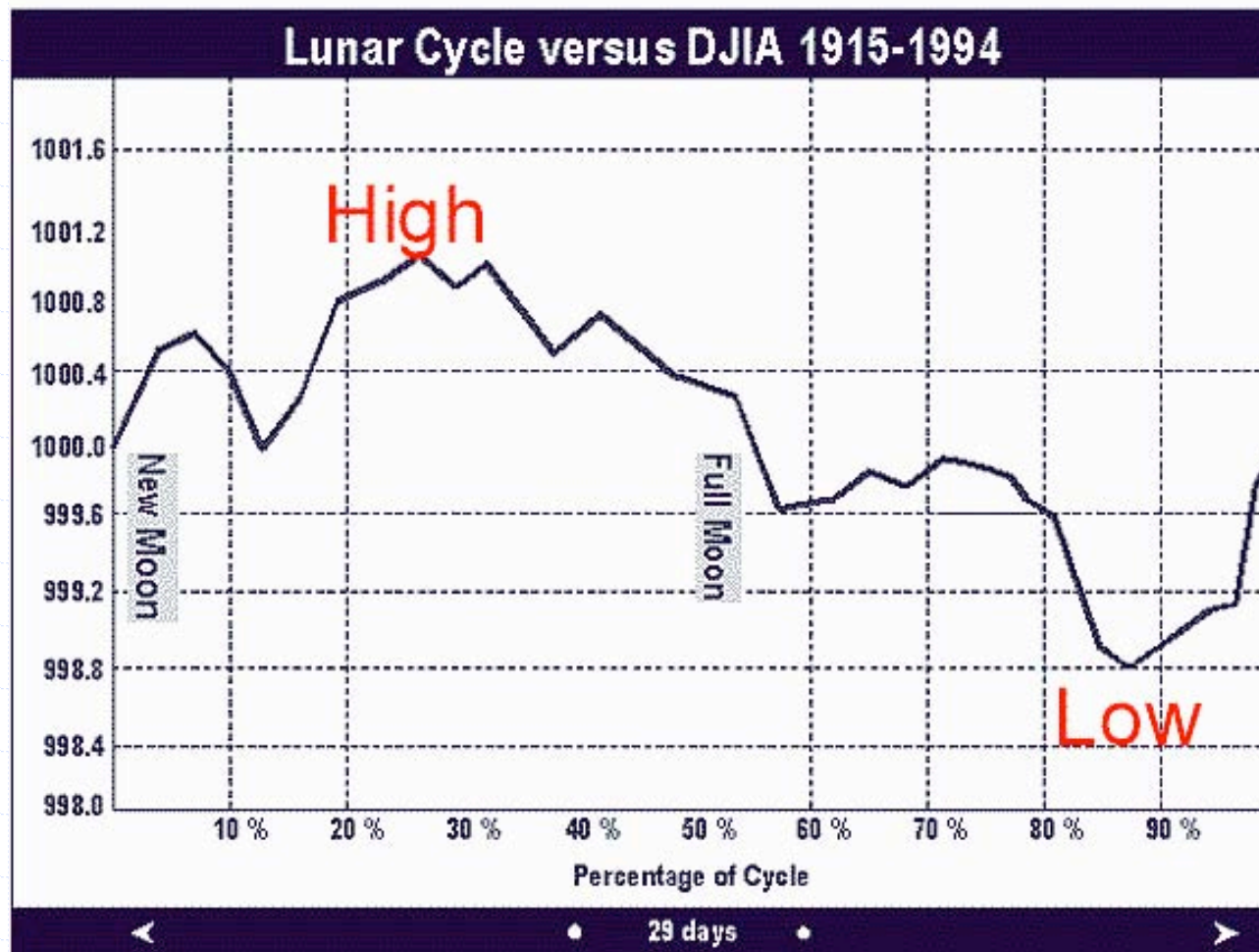


# Moral of the Story

- ◆ “To define an energy efficiency indicator is not only a technical challenge, but also a pre-structuring of the subsequent policy choice.”

ω Aebischer, et al. (2003)

# Correlation is Not Causation!



Advice for Traders: “moon-trading is by no means a stand-alone approach”